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kindly. On the twentieth day came to, or near to, high mountains, called Nanno, running north to south, and thence eastward. Quillingues is surrounded by high sierras. On the twenty-first day came first to the river Humvino, and next to the river Vliume, and on the evening of the next day came to the river Quie, not broad but deep; the days' journeys now became long (10 leagues). The lands here were covered with great trees, abundance of vegetation, and humid plains called Nhanas. On the twenty-third day of the journey came to Culaquimbe, a dependency of Caconda; and next day they entered the Presidency of Caconda, a small fortification, with a garrison, commanded by Joaquim Ferreira de Andrade. The country around this is healthy and fertile. Near the fort is the deep, sluggish river Cathape. Rivulets are numerous, and always have water. All tropical produce thrives here, as the land is excellent. Sugar, coffee, &c., can be produced in any quantities. The country of Quando, one day's journey distant eastward, is extensive, and has a considerable river of the same name, which runs to the Cuncue, but it is not navigable on account of great stones and waterfalls in its bed. The river Quando is three days east of Caconda, and the Cunene about five days. The river Cunene is similarly impeded. Caconda has a church covered with straw. To the south-south-east of Caconda is the country of Irumbo, where the river Cunene, its eastern boundary, is, according to Brocheda (p. 190), only from 50 to 60 fathoms broad—say 330 feet.

The distance from the river Caculavale to Caconda is about 40 leagues, which may be taken at 100 geographical miles. The river Cubango is the western boundary of the Quillingues, a numerous people that spread over the country eastward to near the river Leambaye, and north-east, beyond Bihe, to the Lobale.

#### XIV.—*Notes on the Lower Danube.* By Major J. STOKES, R.E.

Communicated by Capt. R. COLLINSON, R.N., F.R.G.S.

*Read, May 9, 1859.*

[For miles above Orsova, the Danube flows between high mountains, which compress its waters into a narrow, rocky channel, through which it hurries with great velocity. These would seem to be the true Iron Gates of the Danube; although the name has been given to the shallow rapids below Orsova.

After passing these rapids, the river is called the Lower Danube, and entirely changes its character. The stream, which had till then been dashing down a rocky bed in one single channel, gradually loses its force, and spreads into several channels through the soft alluvium of the valley, whose features it is constantly employed in changing, adding to this island, destroying that, or creating new ones.

The broad valley through which it flows is bounded on the right by the Servian and Bulgarian Hills, and on the left by the steppes of Wallachia and Moldavia. The right bank, which in its whole course is thus much higher than the left, is generally rocky and unyielding, whilst the left is soft and easily removed by the action of the river.

These general characteristics are maintained to the head of the Delta, and thence continue down the St. George, to within 30 miles of the sea.]

From the Iron Gates to the junction of its last tributary the Pruth, the Danube is swollen by many streams from the Carpathian Mountains, which traverse the fertile plains of Wallachia



and Moldavia. During the 400 miles from the Iron Gates to Galatz, the river, as has been already remarked, frequently spreads into several channels, which re-unite at intervals. The depths in these channels vary so frequently, that their navigation is extremely difficult; for not only do the depths vary with the changing heights of the river, dependent on the floods caused by rains and melting snows, but the beds of the channel are affected, not only from year to year, but from month to month, by the deposits of the river, and by its action on the banks and islands. Thus the charts of the river are of little use for navigation, as they become falsified in a very short time by the frequent changes. There are seasons of the year when vessels drawing 8 or 9 feet of water can ascend to Turna Severin, and even above the Iron Gates; but the current at such seasons is very strong, and it is only during a few weeks that the navigation is practicable for such large vessels.

The principal vessels engaged on this part of the river draw no more than 4 feet of water to enable them to navigate at all seasons, and even these vessels are unable to pass the rapids of the Iron Gates during the autumn. Sea-going vessels seldom, if ever, ascend the river beyond Oltenitza, and, for sailing vessels, it is considered an unwise operation to go even so high, because the distance for which they have to contend against a still strong current is so great that it generally pays better to bring the corn, which is the staple produce of the country, down to Ibraila. Indeed, it is generally supposed that eventually all produce will be taken to the mouth of the river, and shipped in the port that will be afforded in the St. George mouth, as the width of that branch will permit of the river craft being towed economically, an operation that cannot be effected in the narrow Sulina, the only branch navigated at present.

Before Galatz, the Danube continues in one noble stream in a south-easterly direction to the head of the Delta, a distance of 45 miles. For this space it preserves an average width of three quarters of a mile, and a depth of at least 28 feet, which is sufficient for all purposes of navigation.

At the Ismail Chatal (or fork) the Kilia Branch, containing 17-27ths of the whole stream, takes a northerly direction, and after passing the towns of Ismail and Kilia, forms a delta of its own, through which it discharges itself by five principal mouths into the Black Sea.

The Kilia branch preserves the characteristic which has marked the river between Turna Severin and Galatz. Below Ismail it separates into three channels, all of which are, however, navigable. These channels reunite at Staroi Kilia, 2 miles below the town of Kilia, and 5 miles lower down it again divides into three branches, which unite near the hamlet of Bazartchuk, to form the large

basin of Wilkovi, whence spring the five principal channels which form the Kilia Delta.

Below the Ismail Chatal, the remaining 10-27ths of the stream continue the general south-easterly direction of the main river. In passing the town of Toultscha, however, the river makes a sudden bend, caused by a projecting spur of one of the Babadagh Mountains which here stands forth into the stream, and constitutes the danger known to mariners as the Toultscha Rock. The danger consists in the eddies which play round the point of the rock, a detached portion of which is submerged: vessels striking upon this point sink in a depth of 80 feet. The danger is, however, so well known, that accidents are not frequent, although vessels are sometimes wilfully injured on the rock by the pilots, in order to obtain employment for their friends in Toultscha.

At 6 miles below Toultscha, or 11 below the Ismail Chatal, the river becomes again divided, 3-4ths of the Toultscha branch, or 8-27ths of the whole river, continuing the s.e. direction under the name of the St. George branch, and the remainder—"the Sulina"—flowing in a general easterly direction to the sea.

The St. George, although the most tortuous of the branches of the Danube Delta, possesses the advantage over the Kilia of maintaining itself in one broad deep channel until just before reaching the sea, whilst it is superior to the Sulina in being free from the numerous shoals which obstruct the course of the latter, and in possessing a navigable channel three times wider than the Sulina in its best part.

The St. George may be considered the most southern branch of the Danube, for the little stream of Dunavitza, which connects it with the lake Reazelm, is too insignificant to deserve the title of "branch of the Danube," which has been bestowed upon it by some writers.

The St. George is not yet used by vessels trading to the Danube, as its entrance is obstructed by a bar, through which the unaided current has been unable to maintain a navigable channel. At about a mile and a half from the sea the St. George divides into two channels, of which the northern or Kedrilis branch takes nearly 2-3rds of the river in an e.s.e. direction to the sea, and the remainder, or Olinka channel, flows nearly south.

The Sulina, which is the least of the branches of the Danube, conveying as it does only 2-27ths of the main river to the sea, has nevertheless, up to the present time, maintained the deepest channel through the bar by which the sea strives to continue the line of coast.

The course of this branch is, however, such as to hinder very much its navigation, either by sailing or steam vessels. Immediately at the point where it leaves the St. George (called the

St. George Chatal) it makes such a sudden curve as to form a very acute angle with the main stream above; the sand banks formed at the apex of this angle and on the opposite point render the passage between the Sulina and the Toultscha branch, either up or down, exceedingly difficult at all times. From the St. George Chatal until within 25 miles of the embouchure, the bed of the Sulina is obstructed by eight principal shoals, which either reduce the depth, right across, to only 9 feet, or narrow the channel to such an extent as to cause frequent damage and delays in the navigation.

Mention must not be omitted of an insignificant stream, called the Chouga, which connects the Kilia with the Sulina.

The branches of the Delta and the Chouga form three principal islands, namely, between the Kilia and Toultscha branches that of Chatal, between the Sulina and Kilia that of Leti, and between the Sulina and St. George that of St. George.

Below Galatz the banks of the river present nearly the same features as above that town, with the exceptions that will be noticed.

Its immediate banks are, for the most part, low, being somewhat higher than the level of ordinary floods, but decidedly above the level of the marsh land, extending from the river to the steppe on the left bank, and to the Dobrudscha Mountains on the right.

These marshes are covered with high reeds, except where extensive lakes stretch inland. These lakes are fed by the river itself, which finds its way to them through frequent breaks in the banks, which, as has been intimated, form, as it were, low ridges between the river and the marshes.

In times of extraordinary floods, which happen about once in five or six years, the river overflows these banks and, joining the lakes, covers the broad valley through which the river flows. According to information obtained from old inhabitants in the country, it would seem that this inundation does not extend over the whole Delta to the sea, but that the channels of the river are sufficient lower down to carry off the surplus water.

During the two years, however, that reliable, continuous observations have been made in the Delta of the Danube under the orders of the European Commission, no extraordinary floods, and consequently no extensive inundations, have occurred; and such is the vagueness with which those best acquainted with the country give their information, that little value is to be attached to it.

It is to be hoped that future years will afford opportunities for observing and recording all details that are now wanting concerning extraordinary floods.

The exceptions to the formation of the banks above mentioned

are to be found principally on the right bank, where, at many points, the spurs of the Dobrudscha or Babadagh Mountains approach the river and form its bank. This continues down the St. George to within 30 miles of the coast, and at the point where the range terminates it will furnish a good quarry of hard limestone, whence a good supply of rubble can be obtained.

On the left bank of the main stream and of the Kilia branch the "Steppe" also occasionally touches the river, though not so frequently as the rocky hills do on the other side.

The Delta generally is covered with a dense mass of reeds from 10 to 12 feet high, but there are also on the more elevated parts of the St. George and Leti Islands forests of ash and stunted oak, which latter furnish excellent timber for ship building; and the banks of the St. George and Kilia abound in many places with willows of large growth.

The banks at the mouth of the Sulina are covered with reeds for miles inland, but near the basin of Wilkovi, and the mouth of the St. George, there are tracts of pasture-land of some extent, and at these parts the level is higher, though the soil is more sandy than in the parts covered with reeds.

The data upon which to form a judgment of the growth of the Delta of the Danube are not so extensive as could be wished, but happily they are sufficiently accurate for the measurement of the progress of the northern portion of the Delta; that of the southern part can only be inferred.

A map of the Principalities made in 1769 to illustrate the campaign made by Russian armies in that year, shows the Kilia debouching in one mouth at the point where we now find the Wilkovi basin. There is good reason to believe that this is correct, for there exists to this day a range of sand hills, similar to those now found near the coast, and which were in all probability the coast boundary at that time.

Another Russian plan without date, but giving the city of Odessa, which was built in 1796, shows the mouth of the Kilia at the same point, but indicates the commencement of a formation of islands in front of it, which seem to have given rise to the form of the Kilia Delta.

From this old embouchure to the present coast line of the Delta is a distance of 5 miles, which may be taken as the advance of the Delta, certainly since 1769, and probably during the last sixty years.

In the years 1829-30 a detailed survey of this coast, so far south as Sulina, was made by the Russian Government, and furnishes a certain basis from which may be calculated the advance of the Delta between that period and the year 1857, when the coast was again surveyed by the officers of H.M.S. *Medina* under

the orders of Captain Spratt, R.N. A comparison between the two surveys shows that in twenty-seven years the Kilia Delta has advanced more than 4000 feet; that the line of 4 feet soundings has advanced 4695 feet to the east, and 5754 feet to the south; and that the Massurah Point has also advanced 2250 feet to the south.

This comparison shows the possibility and probability of the great growth since 1796, because, as the arc of the Delta becomes longer, its advance eastward is naturally at a slower rate.

If the old charts, just quoted, are also correct in all their details, the changes in the course of the river from Galatz to the sea must have been very marvellous. It seems, however, probable that the river in those charts was laid down from a bird's-eye view; and if at that time the river had inundated its banks, it would have presented very much the appearance given to it, without giving rise to the supposition that any very remarkable changes have taken place in its course.

Both the old chart of 1769, and that subsequent to 1796, represent the Sulina as a stream of great magnitude. This may arise from its having been the only navigable entry. At all events the correct charts of 1830 show it in very much the same condition as at present, as regards size and position. A remarkable change has, however, taken place in the basin into which it discharges, which cannot be attributed to its own unaided action, but should probably be assigned to the adjacent mouths of the Kilia.

The Sulina bar is now very much in the same position as it was in 1830: the coast line to the north of it instead of advancing has somewhat receded, although to the south it has gained, and is *daily* gaining, on the sea. But in 1830 the 30 feet line of soundings was very close to the bar, resembling very much the present condition of the soundings off the mouth of the Ochakoff branch of the Kilia; whereas in 1857 the 30 feet line was 3200 feet more to seaward, the 20 feet line 1400 feet, and the 12 feet line 450 feet farther out.

These facts draw their significance from the farther one that the prevailing wind and littoral current are from north to south. Thus, during the greater part of the year, the river current is turned southwards, and its deposits, as is the case with the other branches, are found to the south.

Whence, then, has the great filling up to the north and east of the Sulina arisen?

Regarding the rapid southerly advance of the Kilia Delta, the direction of the prevailing wind and littoral current, and the proximity of the Sulina to the southern branches of the Kilia, it seems highly probable that the filling up is due to the deposits of the Kilia, rather than to those of the Sulina itself.



At the mouth of the St. George there would not seem to have been so rapid an advance eastward as at the other embouchures, but the absence of detailed plans of this part of the coast, of earlier date than 1856, prevents such a comparison as has been made of the other mouths.

The general position of this mouth, however, shows that the delta does not advance so rapidly as the northern and central parts, and at the same time the greater depths in front of it show that a filling up from the deposits of the northern branches is *not* taking place.

Farther, the existence of the sandbanks south of the mouth shows that the effect of the prevailing northerly winds and of the littoral current has been to turn the river current and its deposits southwards, and thus the principal channel over the bar has obtained an easterly direction.

An examination of the Black Sea will show that in the small angle formed by the peninsula of the Crimea with its western shore, four large rivers discharge their waters into the sea to the northward of the St. George, namely, the Dnieper, Bug, Dniester, and Kilia, or largest branch of the Danube. The waters of these rivers form a littoral current, which, pressed by the prevailing winds against the coast, seeks to escape round the promontory off the mouth of the St. George, and thus produces the rapid declivity which the soundings show at that point. Thence the current passes down the coast to seek an outlet by the Bosphorus, through which, as is well known, there is a very rapid and constant current from north to south, except after a long succession of southerly winds.

The velocity of the littoral current has never been measured during a perfect calm. It varies with the direction and force of the wind from half a knot an hour to one knot and upwards.

The only observation of it during a perfect calm was furnished during last winter in the following manner :—

Two vessels were descried from the Sulina light-house off the Kilia in the drift ice ; there was no wind, and their sails hung to the masts : by evening they were nearly out of sight to the southward, as the days could not then have been more than ten hours long ; and these vessels must have been drifted fifteen miles by the current : the latter would seem to have had a velocity of  $1\frac{1}{2}$  miles per hour at that time, though it is not usual to calculate it at more than one knot.

The following statistics are taken from the excellent Report of Mr. Hartley, Civil Engineer, and Engineer-in-chief to the European Commission of the Danube.

At a time of ordinary flood, in May—June, 1857, the following quantities were measured in the different branches of the river :—

	Cubic feet per minute.
Main Stream above Ismail Chatal .. .. .	19,522,000
Kilia Branch .. .. .	12,041,000
Toultcha Branch .. .. .	7,309,000
St. George Branch .. .. .	5,771,000
Sulina Branch .. .. .	1,446,000

Again, the measurement of the various branches at their mouths gave the following:—

## KILIA.

	Cubic feet per minute.
Stamboul Branch .. .. .	6,242,000
Ochakoff .. .. .	3,050,000
Peschana .. .. .	1,849,500
Ankodinovo .. .. .	182,500
Bolgrod .. .. .	107,000
Total .. .. .	11,431,000

## ST. GEORGE.

	Cubic feet per minute.
Kedrilis Branch .. .. .	3,890,000
Olinka .. .. .	2,000,000

These floods lasted for about three months; after their subsidence the Sulina was gauged, and the discharge was found to be only 561,100 cubic feet per minute, instead of 1,446,000, or a little more than a third. It is probable the discharge of the other branches had diminished in the same proportion.

“The result of several experiments to ascertain the comparative amount of deposit held in suspension at times of ordinary summer-floods, and when the river has diminished to an average flow, showed that the mean bulk of sedimentary matter, when solidified into coherent earth, is about  $\frac{1}{2400}$  parts of the volume of water in which it is suspended at the former period, and about  $\frac{1}{3300}$  at the latter.”

The surface of the Delta falls to the sea at a slope of about five inches to a mile.

The inclination of the surface of the river varies considerably, and of course its velocity changes accordingly.

During ordinary spring and summer floods the waters of the Sulina have an average fall of 3 inches in the mile, and velocity of  $2\frac{1}{2}$  miles per hour. When the waters are low, their fall barely exceeds  $1\frac{1}{2}$  inches per mile, and their velocity one mile per hour.

The direction and force of the wind exercise an important influence upon the growth of the Delta.

No measurements of the wind's force have yet been made by means of correct instruments for that purpose, but experience has shown that the most violent and longest of duration are from the N. to N.E. Storms from the E. and S.E. generally veer to the N.E.

The recorded observations from December 1856, to September

1858, show that winds from the northward, *i.e.* from N.W. to N.E., were equal in frequency to winds from all other points of the compass; that of these latter, two-thirds were from the westward and southward, or from N.W. to S., which winds blew with little force, and that only the remaining one-sixth of all the winds recorded blew from the eastward and southward, or from points between E. and S.S.E. Thus, during only one-sixth part of the period named was the littoral current actually checked; during one-third of the period it was pushed away from the coast; and during half of the time it was accelerated and pressed against and along the coast by the most violent and lasting of the winds.

These points have been thus put forward because they seem to throw light on the formation of the Delta.

It would be useful to examine what bearing they have on the means to be attempted for deepening the entry.

Two systems have been proposed for effecting this object at the mouth of the St. George. One is, to carry out piers in a direction E. by S. in continuation of the Kedrilis or northern channel, to a depth of 20 or 25 feet, so as to lead the river current through and beyond the bar to a point where the breakers will not cause it to re-form.

The other system is to cut a lateral canal from the deep channel of the river to a point 1000 yards north of the Kedrilis embouchure, where a small artificial harbour shall be constructed to receive it. The entry to the canal from the river to be closed by two sets of gates to prevent the muddy river-water from passing into the canal.

The advocates of the latter system argue that no other means are possible, as they are of opinion that shortly after the piers of the former system shall have enabled the river to cut a channel for itself through the present bar, a new bar will form in front of the piers at about 1000 yards from them, as they assert that the river will throw down the matters held in suspension so soon as the velocity is checked by the inert mass of the sea, and that thus the piers will fail to produce any permanent effect.

On the other hand, the advocates of the piers contend that as the river will not meet a quiescent mass, but one moving generally at the rate of a mile an hour from N. to S., its deposits will be thrown down to the south of the entry, and they appeal to the position of the present sand-banks in support of their argument.

They moreover urge that the bar is not altogether due to the deposits of the river, for, although at the time of a heavy land-flood the bar rises in height, this additional deposit is soon swept away, and the bar remains generally at the same distance from the shore, and is not constantly growing to seaward, as would be the case if the river was daily adding to it.

The bar would seem rather to be due to the action of the waves which strive to continue the line of coast. The river bears its mud far out to sea, leaving the coarser particles near the coast. The waves beat these up and mix with them shells and other productions of the sea. The bar is formed where the waves break on the coast and struggle to stop the river current.

If this current is carried out into the deep water, the supporters of the pier system expect that the bar will not re-form until the general line of coast shall have advanced so far that the breakers again begin to beat upon the shore in front of the current, and when that takes place the piers must be prolonged.

The advance of the coast at the mouth of the St. George has always been slower than on the northern and central portion of the Delta, which is considered to be due to the strong action of the littoral current at this point. It is expected that for a long course of years this current will keep the mouth of the piers free from obstruction by a new bar.

The navigation of the Danube numbers at present rather more, on an average, than 2000 vessels a year, having a burden of nearly 500,000 tons.

The greater part of these vessels enter in ballast, and load with corn, principally Indian corn. Wheat and other grain, horns, timber, hides, tallow, and salt are also exported.

The timber, a soft pine, is rafted down from the Carpathian Mountains to Galatz, whence it is either shipped or formed into much larger rafts for towing to the Bosphorus.

In Bulgaria there is abundance of oak of a description well suited for ship-building, but the Turks will not allow it to be cut for sale; although the forests are seriously injured to a large extent by the peasants, who may cut down the finest trees at their pleasure for firewood, a licence which they abuse most wantonly. The Turkish law relative to oak timber acts very detrimentally upon ships frequenting the Danube, as they have difficulty and are put to immense expense in procuring hard timber for repairs, although abundance is close to them.

The Danube and neighbouring lakes abound in fish of various kinds, of which the sturgeon or maron is especially fine. Large quantities are taken yearly, from which excellent caviar and oil are obtained; the flesh is salted down.

The fisheries are farmed by the Government to individuals who have the exclusive right to fish.

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